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Assessment of the Pennsylvania Housing Research Center Alternative Code

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Summary

The Pennsylvania Housing Research Center (PHRC) has created a proposed alternative path for complying with the energy efficiency provisions of the International Code Council's *2000 International Energy Conservation Code* (IECC) or the *2000 International Residential Code* (IRC) for residential buildings (ICC 1999, 2000). (The proposed alternative path is referred to as the "PHRC proposal" [PHRC 2000]) The Pennsylvania Department of Labor and Industry requested that the U.S. Department of Energy (DOE) evaluate the PHRC proposal to determine whether it meets or exceeds the energy efficiency requirements of the IECC. Under DOE's direction, Pacific Northwest National Laboratory (PNNL) reviewed and assessed the PRHC proposal.

The PHRC proposal has slightly more-stringent energy efficiency requirements than the IECC for some building designs, and slightly less-stringent requirements for other designs. Most of the PHRC proposal requirements are identical or very similar to alternative requirements in the IECC. The PHRC proposal will not comply with the energy efficiency requirements of the IECC for each and every new residential building. If typical new home characteristics are consistent with the survey data in the PHRC Report #68 (Burnett, Bentz, and Fortney 2000) and the PHRC compliance path is used for all homes, the PHRC proposal will result in a Pennsylvania state code that will meet or exceed the IECC in energy efficiency, on average, for all new residential buildings combined. However, builders could predominantly select the PHRC alternative path when it lowers stringency relative to the IECC and rarely use the PHRC path when it increases stringency. The PHRC proposal does not have major deficiencies that will allow any single house to be a "disaster" in terms of energy efficiency compared with the IECC. The PHRC proposal is considerably simpler than the IECC for builders to comply with and code officials to enforce, so code compliance rates may be higher if the PHRC proposal is an allowed alternative.

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1.0 Introduction

The Pennsylvania Department of Labor and Industry requested that the U.S. Department of Energy (DOE) evaluate the Pennsylvania Housing Research Center (PHRC) proposed alternative path to compliance with the International Code Council's *2000 International Energy Conservation Code* (IECC) or the *2000 International Residential Code* (IRC) for residential buildings (ICC 1999, 2000). (The proposed alternative path is referred to as the "PHRC proposal" [PHRC 2000].) The goal of this evaluation was to determine whether the PHRC proposal meets or exceeds the energy efficiency requirements of the IECC and can be included in new Pennsylvania regulations as an acceptable alternative. Under DOE's direction, Pacific Northwest National Laboratory (PNNL)[(a)] reviewed and assessed the PRHC proposal. This report contains the results of this evaluation.

Section 2.0 of this report provides an overview of policy issues that the state of Pennsylvania may want to address when making a final decision on whether to include the PHRC proposal in their state code. Section 3.0 contains a summary of the requirements in the PHRC proposal. A detailed assessment of the PHRC proposal is given Section 4.0. The conclusions from the evaluation are provided in Section 5.0. Section 6.0 contains a list of references cited in this report. Attachments 1 through 11 contain the MEC*check* and RESFEN output reports showing the impacts of the most significant decreases in stringency in the basic envelope requirements in the PHRC proposal.

(a) The Pacific Northwest National Laboratory is operated by Battelle for the U.S. Department of Energy.

2.0 Overview of Policy Issues

Before addressing the technical details of the PHRC proposal, we want to raise the following important policy issues. The state of Pennsylvania may wish to address these issues when making a final decision on whether to include the PHRC proposal in their state code.

1) Does each and every new house (or apartment or condominium) built in Pennsylvania have to comply with the IECC? In other words, does every new house have to use equal or less energy than would result from compliance with the IECC?

If the answer to this question is yes, then the PHRC proposal clearly does not comply with the IECC. For example, if a high proportion of a home's exterior wall area is window area, then the house can comply with the PHRC proposal and fall well short of the IECC.

If the answer to this first question is no, then the second policy question should be asked.

2) Does the PHRC proposal have to comply with the IECC on average, considering all new residential units in Pennsylvania; i.e., does the total combined energy use of all new residences statewide have to not increase if the PHRC proposal were adopted?

We believe Pennsylvania's answer to this question is yes. If so, further policy questions should be addressed.

3) Should the energy efficiency of the PHRC proposal be evaluated assuming the PHRC proposal would be used for every new residence?

For some residences, the PHRC proposal requirements are more stringent than the IECC requirements; for other residences, the PHRC proposal requirements are less stringent than the IECC requirements. If the PHRC proposal was used for every new residence, and the characteristics of these residences (window area as a percentage of wall area) match what we believe is common, the PHRC proposal should outperform the IECC in terms of energy efficiency on a statewide average. However, the PHRC proposal is intended to be an alternative to the IECC. Therefore, builders could selectively use the requirements in the PHRC proposal. When the PHRC requirements are less stringent than the IECC, they can use the PHRC compliance path. If builders use this compliance path this way, the IECC plus the PHRC alternative would not meet the IECC on a statewide average.

On the other hand, the PHRC proposal requirements are simpler (do not require window and wall area calculations) than those in the IECC and therefore may often be used even when they are more stringent than the IECC. We believe the PHRC proposal will often be used instead of the IECC (although we cannot prove this belief) regardless of whether it increases or decreases energy efficiency. If this belief holds true, the IECC plus the PHRC alternative will likely meet or exceed the IECC on a statewide average.

4) Will the PHRC proposal ensure reasonable energy efficiency for every house?

If the state accepts that the PHRC proposal does not have to meet the IECC for every residence but will likely meet the IECC "on average," we are sure the state will also want to prevent any grossly inefficient housing from being built. A homebuyer whose house has very high energy bills will not be consoled by the fact that most of the neighbors have low energy bills. The PHRC proposal does

ensure that houses will be built with a reasonably good level of energy efficiency. One noteworthy element of the PHRC proposal is that it allows unconditioned basements to be completely uninsulated if extra high efficiency HVAC equipment is used. This type of trade-off is allowed by the IECC if justification is provided using a valid energy analysis—something PHRC has done. This trade-off may not be a good idea for non-energy reasons because it will likely result in cold, damp basements.

3.0 Summary of PHRC Proposal

The PHRC proposal is a 13-page document referred to as an, "alternative Chapter 11," because the IRC energy efficiency requirements are contained in Chapter 11 of the IRC (PHRC 2000). The IRC contains a condensed and substantially simplified version of the residential energy efficiency requirements of the IECC. The IRC also contains the IECC by reference. The core of the PHRC proposal is a simple table (Table PA1103.1) of basic requirements for the building envelope (ceiling, wall, floor, and foundation R-values; window and skylight U-factors) for three climates zones covering Pennsylvania. In general, the PHRC proposal envelope requirements are identical or very close to those contained in the IECC (the prescriptive specification path in Section 502.2.4). Because PNNL developed the requirements in Section 502.2.4 of the IECC, we know these envelope requirements exceed the minimum energy efficiency requirements in the IECC by a few percent on average, which is consistent with the findings of PHRC Reports #70 and #71 (Fortney and Burnett 2000; Lau and Fortney 2001). The PHRC proposal also has provisions for air leakage control, thermostats, duct insulation and sealing, and piping insulation, generally matching the provisions in the IRC and IECC.

A variety of elements of the PHRC proposal do not strictly comply with the their counterparts in the IECC. These elements are listed below and are individually examined in more detail in Chapter 4.

- The IECC has energy efficiency requirements that vary with the window-to-wall area percentage of the residential building. The IECC requirements become more stringent as the window-to-wall area percentage increases. The general idea here is that windows increase energy use, so the IECC penalizes houses with a high proportion of window area. The PHRC proposal has efficiency requirements that do not vary with window-to-wall percentage. This method makes the PHRC proposal simpler in appearance, and more importantly, much simpler for builders to comply with and code officials to enforce. The PHRC proposal will often not meet the energy efficiency requirements of the IECC when the window-to-wall percentage of a house is high (above 16%), although the PHRC proposal tends to exceed the IECC in stringency when the window-to-wall percentage of a house is low. Data collected for new houses mainly in the Philadelphia area (Burnett, Bentz, and Fortney 2000) suggest typical window-to-wall percentages are low enough (averaging 12%) that the basic envelope requirements of the PHRC proposal meet or exceed the IECC, on average.

- Walls next to unconditioned spaces (such as a wall between the house and a garage) are allowed to have only R-13 insulation, whereas the equivalent requirements in the IECC vary from R-16 to R-21 in Pennsylvania.

- Skylights are allowed to have higher (less energy-efficient) U-factors—generally 0.15 higher than the IRC/IECC requires.

- The PHRC proposal has duct insulation requirements of R-4.3 instead of the IECC's R-5 for ducts in unconditioned spaces, and R-6.4 instead of the IECC's R-8 for ducts located outside the building.

- The R-value requirements for insulation levels in steel-framed walls vary slightly from those in the IECC. The PHRC requirements are approximately equal in stringency, however.

- In the Northern zone only, cathedral ceilings and floors over outside air are allowed to have R-30 insulation instead of the IECC requirement of R-38. However, the Northern zone is the least populated, and the energy impact of the reduction in R-value is small.

- Four square feet of windows are exempt from energy efficiency requirements, a slight increase from the IECC's exemption of two to three square feet for most houses. This change is negligible.

- Doors are allowed to have a slightly higher U-factor of 0.39 instead of the IECC's 0.35 (note that one door is exempt from U-factor requirements in both the PHRC proposal and the IECC). This change is negligible because of the small change in U-factor and the small amount of envelope area affected.

The PHRC proposal requirements include several specifically defined "trade-offs," where an improvement in one aspect of a building's energy efficiency that exceeds the code's basic requirements allows another aspect to fall short of the code's basic requirements. These types of trade-offs are clearly permitted by the IECC if overall energy efficiency is maintained. In the PHRC proposal trade-offs, the building elements that are allowed to fall short of the basic IECC requirements are window U-factors, wall insulation, and/or foundation insulation. The compensating elements that need to exceed the basic requirements are air infiltration (leakage) control and/or heating and cooling equipment efficiency. Most of the PHRC proposal trade-offs maintain or improve overall energy efficiency. The trade-off that allows an unconditioned (typically unfinished) basement to be completely uninsulated (no insulation in the basement wall or the floor above the basement) appears to be valid based on computer simulations, at least if the HVAC system is not installed in the basement. The PHRC proposal would allow this trade-off if high-efficiency heating equipment were used (high-efficiency air conditioners would also be required in the Southern zone).

4.0 Detailed Assessment of the PHRC Proposal

This section provides a detailed assessment of the envelope requirements in the PHRC proposal based on our evaluation (PHRC 2000). The envelope requirements in the IRC/IECC and PHRC proposal are compared and the impacts of the differences in these requirements are provided.

4.1 PHRC Basic Envelope Requirements

The PHRC table of basic thermal envelope component requirements (Table PA1103.1) is the heart of the proposal's energy efficiency requirements. This table is reproduced in Table 4.1 below. These requirements are generally the same as those required by Chapter 5 of the IECC. More specifically, the PHRC requirements are generally the same as the IECC's prescriptive individual component requirements (Section 502.2.4) for Type A-1 (single-family or duplex) houses with a 15% window-to-wall area percentage and Type A-2 (multifamily) with a 25% window-to-wall area percentage. The important issue of window-to-wall area percentage is discussed in considerable detail below.

Table 4.1. Basic Thermal Envelope Requirements in the PHRC Proposal

Climate Zone	Maximum U-Factor			Minimum R-Value							
	Fenestration		Skylights	Roof/Ceiling		Walls		Floors Over Non-Conditioned Space	Slab Perimeter R-Value and Length	Basement Walls	Crawl Space Walls
	Type A-1	Type A-2		Type A-1	Type A-2	Type A-1	Type A-2				
South	0.45	0.53	0.60	R-38	R-30	R-16	R-13	R-19	R-6, 2 ft	R-9	R-17
Central	0.40	0.51	0.55	R-38	R-30	R-18	R-13	R-21	R-9, 4 ft	R-10	R-19
North	0.35	0.45	0.50	R-49	R-38	R-21	R-16	R-21	R-13, 4 ft	R-11	R-20

Page 13 of PHRC Report #70 points out that in two cases the PHRC proposal results in a small decrease in stringency compared with the IRC/IECC, and in one case the proposal results in an increase in stringency (Fortney and Burnett 2000). Table 4.2 shows these differences. Additionally, we identified four more changes from the IRC/IECC to the PHRC proposal (also shown in Table 4.2). Three of these four additional changes are for multifamily buildings. Of these seven differences, the PHRC proposal is less stringent than the IECC in five cases and more stringent in two cases.

We examined the impacts of the most significant decreases in stringency in the basic envelope requirements in the PHRC proposal. Using MEC*check* 3.0 (PNNL 2000), the change from 0.35 to 0.40 windows in IRC/IECC Zone 13 (city examined was Wilkes Barre) increases the whole house conductive heat loss (the "UA") by 3.9%. Even with this decrease in stringency, the Central zone PHRC requirements still barely comply with the IECC in Wilkes Barre. For the reduction in wall insulation from R-18 to R-16 in IRC/IECC Zone 11 (city examined was York), the UA increases by 3.0% but still complies with the IECC. We did not examine the window U-factor increase in Zone 15 because we believe new multifamily buildings in rural and sparsely populated Zone 15 will be rare. See Attachments 1 through 4 for the MEC*check* output reports.

Table 4.2. Differences Between the IRC/IECC and the PHRC Proposal

Zone (IRC/IECC)	PHRC Proposal	Thermal Envelope Component	IRC/IECC	PHRC Proposal
11	South	Wall (single-family)	R-18	R-16
13	Central	Window (single-family)	U-0.35	U-0.40
14	North	Slab	R-11	R-13
Additional Changes Not Identified in Table 3.2 of Report #70				
11	South	Window (multifamily)	U-0.52	U-0.53
15	North	Window (multifamily)	U-0.35	U-0.45
13	Central	Crawl Space	R-20	R-19
14	North	Roof/Ceilings (multifamily)	R-30	R-38

4.2 Consolidation of the Six IECC Climate Zones into Three Zones

The IECC breaks Pennsylvania into six climate zones, Zones 10 (mildest winters) to 15 (coldest winters). The PHRC proposal combines Zones 10 and 11 into a Southern zone, Zones 12 and 13 into a Central zone, and Zones 14 and 15 into a Northern zone. We believe the three zones proposed by PHRC are entirely adequate to represent the climatic diversity and variation in the IECC requirements in the state of Pennsylvania.

4.3 No Penalties for High Window Area Percentages

The IECC has envelope requirements by overall component U-factor. It also has a simplified approach where prescriptive requirements are provided for each envelope component and vary with the window-to-wall area percentage. This type of approach means that for any given house, if more windows are added, the code's requirements become more stringent—more insulation or other improvements are required. In contrast, the PHRC proposal has the same envelope requirements regardless of the window-to-wall area percentage. In PHRC Report #70, PHRC shows that their proposed envelope requirements (Table PA1103.1) are more stringent than the IECC for houses with window-to-wall area percentages below 16% (Fortney and Burnett 2000). The PHRC proposal is less stringent than the IECC for higher window-to-wall area percentages—above 16%. We have not conducted a detailed review of this analysis, but we believe it is accurate based on our knowledge of the IECC envelope requirements. PHRC argues that their proposal is slightly more stringent than the IECC, on average, across all new houses because most new houses in Pennsylvania apparently have window-to-wall area percentages below 16%. PHRC Report #68 reports that the average window-to-wall area is about 12% for 60 new single-family houses and an average of 12% for 15 townhouses (Burnett, Bentz, and Fortney 2000). We do not have any hard data on window areas in the northeastern United States, but our previous research indicates that the average window-to-wall area in new houses is probably in the 12% to 14% range (Conner and Lucas 1994). For Type A-2 multifamily buildings, window-to-wall area percentages may be higher, but the issues and conclusions are the same—the PHRC proposal is more stringent than the IECC at lower window-to-wall area percentages, and most new buildings probably fall into this category.

The argument that the PHRC proposal is equal to or more stringent than the IECC on average, considering the typical window-to-wall area percentages of new houses, is predicated on the condition that the PHRC approach is used for all houses. A builder who is trying to meet the energy code with the lowest possible construction costs can, in the case of the lower window-to-wall area percentages, use the IECC prescriptive or component U-value requirements given in Section 502.2, or the performance approach (Chapter 4). Therefore, builders could use the PHRC requirements only when they decrease stringency and not when they increase stringency. However, builders may use the PHRC approach even if the window-to-wall area percentage is low because of its simplicity.

How much impact does the window area have on total annual energy use? We did simulations using the RESFEN 3.1 software to test determine this impact (Mitchell et al. 1999). We simulated an 1890-ft^2, two-story house with a basement in Pittsburgh. We assumed the home had natural gas furnace heating at a gas cost of $0.75/therm and air conditioning at an electricity cost of 9.0 cents/kWh. Windows with a U-factor of 0.40 and a solar heat gain heat coefficient of 0.55 were assumed to be equally oriented in all four cardinal directions. When window area increases from 16% of the gross wall area (336 ft^2) to 20% (420 ft^2), the total annual energy cost (space heating and cooling) increases by 6%, from $511 to $544. On the other hand, when window area decreases from 16% (336 ft^2) to 12% (252 ft^2), the total annual energy cost decreases by 6%, from $511 to $479. See Attachments 5, 6, and 7 for the RESFEN output reports.

The approach in the PHRC proposal to not address window area may have significant code implementation/enforcement advantages. The principal benefit of decoupling envelope requirements from the window-to-wall area percentage is a substantial improvement in simplicity–no more mandatory calculations of window areas or wall areas. These calculations can be quite complex (gable ends, dormers, basement walls, A-frame houses), and full of chances for error or abuse. A survey of 423 new houses in Florida revealed that 45% of the houses had the window area percentage overreported or underreported by 1% or more (FPL 1995). With the PHRC proposal, all that is needed to determine compliance is the window U-factors and R-values for walls and other envelope components. The PHRC requirements should be less time-consuming and complicated to comply with and enforce. Therefore, there may very well be higher compliance rates. As mentioned above, it is quite possible that builders may use the PHRC approach even when the PHRC requirements are more stringent than other approaches in the IECC (for houses with window-to-wall area percentages below 16%) because of the simplicity.

4.4 R-13 Requirement for Walls Adjacent to Unconditioned Spaces

The PHRC proposal would allow R-13 for walls next to unconditioned spaces such as garages, attics, unheated basements, and crawl spaces. Walls between the house and the garage are expected to be the most common situation where this requirement would apply. The R-13 requirement is proposed for all of Pennsylvania. PHRC's justification is that the unconditioned space provides some insulating benefit.

The energy penalty for R-13 walls depends on what insulation level the walls would otherwise be required to have. The IECC requires R-16, R-18, or R-21 walls in Philadelphia, Pittsburgh, and Bradford, respectively, for a house with a 15% window-to-wall area. We used MEC*check* 3.0 (PNNL 2000) to estimate the impacts of using R-13 instead of the IECC requirement of R-18 in Pittsburgh for a 20-ft-long by 8-ft-high wall next to a garage. The whole-house conductive heat loss (UA) increased by 1% because of the lower insulation. The actual impact should be somewhat less than this 1% because the MEC*check* estimates assume the 160-ft^2 R-13 surface is directly exposed to outside air, neglecting the benefit a garage or other unconditioned space provides in reducing heat loss. We suspect the temperature of the

typical garage is only slightly above the outside air temperature in winter and therefore provides little benefit. Garages typically have completely uninsulated walls and ceilings, and cold air is likely to leak through garage doors (for cars) at substantial rates. Of course, when the garage door is open, the garage will provide essentially no thermal benefit. Garages and other unconditioned spaces do provide the minor benefit of two extra air films (a very thin layer of air that clings to the surface of the walls and provides an R-value of about 0.5). An energy efficiency loss of 1% or less is acceptable given that the PHRC envelope requirements are at least a few percent more stringent than the IECC minimum requirements for most houses. The example house in Pittsburgh examined using MEC*check* still complies with the IECC by a 2% margin, even with the R-13 walls (see Attachments 8 and 9).

4.5 Less-Stringent Skylight U-Factor Requirements

The PHRC proposal allows less-stringent skylight U-factor requirements than the IRC/IECC, particularly for Type A-1 single-family houses (see Table 4.3). This less-stringent requirement is allowed because skylight U-factors are higher than the U-factors of comparable windows, and few skylight products with U-factors of 0.45 and lower are available. The impact of this less-stringent requirement is expected to be minor given the NFRC reports that, on average, only about one skylight is installed per every two new houses (NFRC 2000). MEC*check* indicates the impacts are minimal–only a 0.3% increase in heat loss (UA) with 8 ft^2 of skylights with a U-Factor of 0.55 instead of 0.40 in Pittsburgh (see Attachments 10 and 11).

Table 4.3. Skylight U-Factor Requirements for Type A-1 Single-Family Houses

Zone	IRC/IECC	PHRC
South	0.45	0.60
Central	0.40	0.55
North	0.35	0.50

4.6 Reduced Duct Insulation Requirements

The PHRC proposal has duct insulation requirements of R-4.3 instead of the IECC's R-5 for ducts in unconditioned spaces, and R-6.4 instead of R-8 for ducts located outside the building. PHRC does not account for the impact of this insulation reduction in any of their analyses. Duct insulation is important, and the requirements in the IECC are not particularly stringent and probably should not be reduced. However, this relatively minor shortcoming is offset by the increase in stringency of the PHRC envelope requirements over the IECC's minimum requirements.

4.7 R-30 Requirement for Cathedral Ceilings and Floors Over Outside Air in Northern Zone

For cathedral ceilings, the PHRC proposal requirement is R-30 for all of Pennsylvania. The IRC/IECC requires R-38 in the Northern PHRC zone if the full thickness of the insulation is achieved over the entire ceiling area. Given 1) the low number of housing starts in the Northern zone, 2) the fact that cathedral ceilings are normally only a minority of the total roof/ceiling area, and 3) the diminishing

returns (energy savings) of increasing insulation beyond R-30, the overall impact of this less-stringent requirement is considered negligible. Allowing R-30 instead of R-38 in cathedral ceilings will often reduce construction costs because high-density R-30 insulation will fit into 2x10 framing while R-38 will not.

For floors over outside air (e.g., overhangs), the PHRC proposal requirement is R-30 for all of Pennsylvania. The IRC/IECC is more stringent in one special case–the IRC and Chapter 6 of the IECC require R-38 in the Northern zone only if more than 25% of the area of the floor assembly is exposed directly over outside air. For small overhangs (less than 25% of the floor assembly area), the PHRC proposal requirement of R-30 is more stringent than the IRC/IECC requirement of R-19 or R-21 for smaller overhangs. On an overall average, the PHRC proposal is probably equal or slightly more stringent than the IRC/IECC for floors over outside air.

4.8 Above-Grade Thermal Envelope Trade-Offs

Section 1103.8 of the PHRC proposal contains several specific trade-off options, where improvements in air infiltration control or heating and cooling equipment efficiency allow lower insulation levels and/or higher window U-factors. Chapter 4 of the IECC clearly allows these types of trade-offs, on the condition that total estimated annual energy use is not increased. Tables 4.4, 4.5, and 4.6 show the decrease in stringency in envelope component allowed if there is 1) a reduction in air infiltration to 0.35 air changes per hour (the PHRC proposal requires verification with a blower door test) or 2) an improvement in heating equipment efficiency from 78% to 90% for natural gas furnaces, or an improvement from 6.8 HSPF to 7.8 or 8.0 HSPF heat pump efficiency (the Southern zone also requires an improvement to a 12 SEER air conditioner). Any one of the three options for decreasing envelope efficiency can be selected if infiltration control or equipment efficiency is improved; two of the three options can be selected if both infiltration control and equipment efficiency are improved. These trade-offs are analyzed in PHRC Report #71 (Lau and Fortney 2001). We believe these three envelope trade-off options are justified and permitted by the rules in Chapter 4 of the IECC. The decreases in envelope efficiency are relatively minor, and are offset or more than offset by the improvement in equipment efficiency or infiltration control.

A fourth thermal envelope trade-off allows unheated basements to be completely uninsulated. This tradeoff can be taken only for the equipment efficiency improvement. It is unclear if this particular trade-off is always justified; this trade-off is discussed in more detail below.

Table 4.4. PHRC Above-Grade Thermal Envelope Trade-Offs, Option A–Decrease in Stringency

Zone	Fenestration Maximum U-Factor		Wall R-Value	
	Type A-1	Type A-2	Type A-1	Type A-2
South	0.45 -> 0.50	0.53 -> 0.55	R-16 -> R-15	No change
Central	0.40 ->0.45	0.51 -> 0.53	R-18 -> R-16	No change
North	0.35 ->0.40	0.45 -> 0.51	R-21 -> R-19	R-16 -> R-15

Table 4.5. PHRC Above-Grade Thermal Envelope Trade-Offs, Option B–Decrease in Stringency

Zone	Fenestration Maximum U-Factor	
	Type A-1	Type A-2
South	0.45 -> 0.55	No change
Central	0.40 -> 0.50	No change
North	0.35 -> 0.45	No change

Table 4.6. PHRC Foundation Thermal Envelope Trade-Offs–Decrease in Stringency

Zone	Floor	Slab	Basement	Crawl Space
South	No change	R-6 -> R-4	R-9 -> R-7	R-17 -> R-11
Central	No change	R-9 -> R-6	R-10 -> R-8	R-19 -> R-13
North	No change	R-13 -> R-9	R-11 -> R-9	R-20 -> R-19

4.9 Basement Insulation Trade-Off

Part 3 of Section 1103.8.2 of the PHRC proposal allows unconditioned basements to be completely uninsulated if high-efficiency space-heating equipment is installed (the Southern zone also requires high-efficiency cooling equipment). The basement must be mostly below ground; only 12 in. or less of the basement, on average, can be above grade. The reason for this limitation is that the ground provides some insulating value, while an uninsulated concrete basement wall directly exposed to outside air loses heat very rapidly.

Page 102 of the *Building Foundation Design Handbook* (BFDH) gives a heating season energy load (excluding duct losses and equipment inefficiencies) increase of 0.06 MBtu/linear ft of basement perimeter for no basement wall insulation instead of R-10 continuous wall insulation for an unconditioned deep basement in Chicago, Boston, and Seattle (Labs et al. 1988). These cities have similar heating season climates to Pennsylvania (no Pennsylvania cities are included in the BFDH analysis). For the one-story prototype with a 186-ft perimeter considered in PHRC Report #71 (Lau and Fortney 2001), this heating energy load increase is 11.2 MBtu/yr. Assuming a 90%-efficient gas furnace with 10% of the energy lost through duct system inefficiencies, the total heating energy use attributable to eliminating the basement wall insulation is 13.8 MBtu/yr. Basement insulation has a much smaller impact on cooling energy use because of the relatively cool earth temperature in the summer. In fact, the BFDH research indicates eliminating basement insulation slightly decreases cooling energy use (by 1.68 kWh/linear ft for R-10 wall insulation in Chicago). For the one-story prototype, the cooling energy load savings is 1.1 MBtu/yr. Assuming a 10 SEER air conditioner and 10% duct inefficiency, the total cooling energy decreases by 0.4 MBtu/yr.

PHRC analyses using the PowerDOE simulation tool (Hirsch et al. 1998) calculated much lower energy impacts from removing basement wall insulation in unconditioned basements than the BFDH (Lau and Fortney 2001) . PHRC calculated heating load increases of 4.2, 5.6, and 8.4 MBtu/yr in Philadelphia,

Pittsburgh, and Bradford, respectively, for the one-story house with a full basement. This estimate is substantially lower than the BFDH estimate of 11.2 MBtu/yr for comparable climates. In the PHRC analysis, the increased heating loads resulting from the lack of basement wall insulation are more than compensated for by the required 15% improvement in heating equipment efficiency. We cannot explain the difference between the PHRC and BFDH analyses. We have examined the PHRC simulations and they appear sound, although the effects of heating equipment in the basement are not accounted for in the simulations we have obtained. Calculating heat loss through below-grade basements is highly complicated, and any simulation is, at best, a rough estimate. For example, the conductivity of earth is highly variable and depends on the type and moisture content of the soil.

The impacts from a lack of basement insulation will be smaller for a two-story house because the basement is typically smaller and has a relatively lower share of the total building envelope heat loss. Therefore, the basement wall insulation trade-off will perform better in terms of energy efficiency for a two-story house compared with a one-story house.

PHRC Report #71 does not account for a potentially important consideration–if the heating system and/or ducts are located in the unconditioned basement, some amount of heat escapes from the HVAC system to the basement because of air leaks and conduction heat loss. Much of this heat will make it through the basement ceiling and help heat the house. However, some of this heat will pass through the basement walls and be lost. Clearly, more of the heat leaking from the HVAC system will be lost if the basement walls are not insulated. The PHRC analysis we received did not include any increase in heat loss through basement walls from ducts located in the basement, although PHRC reported by personal contact[1] that they did a quick check of this issue and found the impacts to be small. Duct systems in general are notorious for leaking (Treidler 1993). The IECC allows basement ceiling insulation instead of basement wall insulation for unconditioned basements, so the IECC apart from the PHRC proposal does not ensure that HVAC systems in basements are not energy losers.

In summary, we cannot state the basement insulation trade-off proposed by PHRC will not result in equal or decreased energy use in all cases, but PHRC has provided a detailed and valid energy analysis in support of this trade-off (Lau and Fortney 2001). We stress that any ducts in unconditioned basements without wall insulation (and other unconditioned spaces) need to be fully insulated, and ducts and HVAC equipment need to be carefully sealed in accordance with the IECC/IRC code (ICC 1999, 2000). Additionally, it is important to enforce the limit that no more than 1-ft of the basement wall be above grade because an uninsulated concrete wall directly exposed to outside air will lose heat very rapidly.

4.10 Steel-Framed Walls

The PHRC proposal has some slight revisions in the insulation requirements for steel-framed exterior walls. Table 4.7 shows the differences between the IECC (Chapter 6) and the PHRC proposal. On an average across the state, the IECC and PHRC requirements are very similar and approximately equal in stringency, so we believe the PHRC proposed requirements for steel-framed walls are adequate.

[1] Andy Lau, February 5, 2001.

Table 4.7. Steel-Framed Wall R-Value Requirements

IECC/IRC Zone	IECC (Chapter 6)	PHRC
10	R-11+R-9, R-15+R-8	R-11+R-8.5, R-15+R-7
11	R-11+R-9, R-15+R-8	R-11+R-8.5, R-15+R-7
12	R-11+R-9, R-15+R-8	R-13+R-9, R-15+R-8.5
13	R-13+R-10, R-19+R-9	R-13+R-9, R-15+R-8.5
14	R-13+R-10, R-19+R-9	R-13+R-11, R-15+R-10
15	R-13+R-10, R-19+R-9	R-13+R-11, R-15+R-10

5.0 Conclusion

PHRC has proposed an alternative compliance path that is similar to prescriptive requirements in the IECC/IRC with a few amendments and clearly defined trade-offs (ICC 1999, 2000). The Pennsylvania Department of Labor and Industry should consider an important policy issue when deciding whether the PHRC proposal (PHRC 2000) is equivalent to the IECC/IRC in terms of energy efficiency. This issue is whether equivalency must be maintained for every new house (and multifamily building) or on average across all new houses. If equivalency must be achieved on a house-by-house basis, then the PHRC proposal should be rejected because it clearly falls short of the IECC for some house designs.

Our analysis suggests that the PHRC proposal is effectively equivalent to the overall energy efficiency requirements of the IECC on a statewide average if the PHRC code is used for all new buildings. We do not recommend some elements of the PHRC proposal, such as reducing duct insulation, but these elements are not major loopholes and may make the code easier to comply with and lower construction costs. Many new houses built to meet the requirements in the PHRC proposal should be slightly more energy-efficient than the same houses built to meet the minimum IECC requirements. Many new houses built to meet the PHRC proposal may be slightly less energy-efficient. We consider the requirements in the PHRC proposal to be effectively equal in stringency to the minimum requirements in the 2000 IECC, on average. A factor worth noting is that the PHRC alternative compliance path is substantially simpler to use and enforce than any other path in the IRC or IECC.

Again, the conclusion of overall energy efficiency equivalency with the IECC is valid only if the PHRC alternative is used for most new residences. The key point is that the PHRC proposal is an alternative to the IECC and therefore can be used selectively for some but not all new residences. The state of Pennsylvania must be aware that builders could predominantly use the requirements in the PHRC proposal when these requirements are less-stringent than the IECC. If this scenario occurs, the IECC plus the PHRC alternative path may fall slightly short of the energy efficiency of the IECC without the PHRC alternative path.

6.0 References

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Attachment 1

Zone 13 with U-0.40 Windows

_____
Permit Number

MEC*check* Compliance Report

_____
Checked By/Date

MEC*check* Software Version 3.0 Release 1
2000 IECC Edition

CITY: Wilkes Barre
STATE: Pennsylvania
HDD: 6291
CONSTRUCTION TYPE: Single Family

DATE: 02/02/01

COMPLIANCE: Passes

Maximum UA = 318
Your Home = 317

	Gross Area or Perimeter	Cavity R-Value	Cont. R-Value	Glazing or Door U-Factor	UA
Ceiling 1: All-Wood Joist/Rafter/Truss	1418	38.0	0.0		43
Exterior Wall 1: Wood Frame, 16" o.c.	1434	13.0	5.0		92
Door 1: Opaque	56			0.390	22
Window 1: Vinyl Frame, Double Pane with Low-E	246			0.400	98
Floor 1: All-Wood Joist/Truss, Over Unconditioned Space	1418	21.0	0.0		62

COMPLIANCE STATEMENT: The proposed building design described here is consistent with the building plans, specifications, and other calculations submitted with the permit application. The proposed building has been designed to meet the 2000 IECC requirements in MEC*check* Version 3.0 Release 1.

Builder/Designer_____ Date_____

Attachment 2

Zone 13 with U-0.35 Windows

_____
Permit Number

MEC*check* Compliance Report

_____
Checked By/Date

MEC*check* Software Version 3.0 Release 1
2000 IECC Edition

CITY: Wilkes Barre
STATE: Pennsylvania
HDD: 6291
CONSTRUCTION TYPE: Single Family

DATE: 02/02/01

COMPLIANCE: Passes

Maximum UA = 318
Your Home = 305

	Gross Area or Perimeter	Cavity R-Value	Cont. R-Value	Glazing or Door U-Factor	UA
Ceiling 1: All-Wood Joist/Rafter/Truss	1418	38.0	0.0		43
Exterior Wall 1: Wood Frame, 16" o.c.	1434	13.0	5.0		92
Door 1: Opaque	56			0.390	22
Window 1: Vinyl Frame, Double Pane with Low-E	246			0.350	86
Floor 1: All-Wood Joist/Truss, Over Unconditioned Space	1418	21.0	0.0		62

COMPLIANCE STATEMENT: The proposed building design described here is consistent with the building plans, specifications, and other calculations submitted with the permit application. The proposed building has been designed to meet the 2000 IECC requirements in MEC*check* Version 3.0 Release 1.

Builder/Designer_____ Date_____

Attachment 3

Zone 11 with R-16 Wall Insulation

_____
Permit Number

MEC*check* Compliance Report

_____
Checked By/Date

MEC*check* Software Version 3.0 Release 1
2000 IECC Edition

CITY: York
STATE: Pennsylvania
HDD: 5256
CONSTRUCTION TYPE: Single Family

DATE: 02/02/01

COMPLIANCE: Passes

Maximum UA = 352
Your Home = 345

	Gross Area or Perimeter	Cavity R-Value	Cont. R-Value	Glazing or Door U-Factor	UA
Ceiling 1: All-Wood Joist/Rafter/Truss	1418	38.0	0.0		43
Exterior Wall 1: Wood Frame, 16" o.c.	1434	13.0	3.0		102
Door 1: Opaque	56			0.390	22
Window 1: Vinyl Frame, Double Pane with Low-E	246			0.450	111
Floor 1: All-Wood Joist/Truss, Over Unconditioned Space	1418	19.0	0.0		67

COMPLIANCE STATEMENT: The proposed building design described here is consistent with the building plans, specifications, and other calculations submitted with the permit application. The proposed building has been designed to meet the 2000 IECC requirements in MEC*check* Version 3.0 Release 1.

Builder/Designer_____ Date_____

Attachment 4

Zone 11 with R-18 Wall Insulation

_____
Permit Number

MEC*check* Compliance Report

_____
Checked By/Date

MEC*check* Software Version 3.0 Release 1
2000 IECC Edition

CITY: York
STATE: Pennsylvania
HDD: 5256
CONSTRUCTION TYPE: Single Family

DATE: 02/02/01

COMPLIANCE: Passes

Maximum UA = 352
Your Home = 335

	Gross Area or Perimeter	Cavity R-Value	Cont. R-Value	Glazing or Door U-Factor	UA
Ceiling 1: All-Wood Joist/Rafter/Truss	1418	38.0	0.0		43
Exterior Wall 1: Wood Frame, 16" o.c.	1434	13.0	5.0		92
Door 1: Opaque	56			0.390	22
Window 1: Vinyl Frame, Double Pane with Low-E	246			0.450	111
Floor 1: All-Wood Joist/Truss, Over Unconditioned Space	1418	19.0	0.0		67

COMPLIANCE STATEMENT: The proposed building design described here is consistent with the building plans, specifications, and other calculations submitted with the permit application. The proposed building has been designed to meet the 2000 IECC requirements in MEC*check* Version 3.0 Release 1.

Builder/Designer_____ Date_____

Attachment 5

RESFEN 3.1 Output – 12% Window-to-Wall Area

Attachment 6

RESFEN 3.1 Output – 16% Window-to-Wall Area

Attachment 7

RESFEN 3.1 Output – 20% Window-to-Wall Area

Attachment 8

Garage Wall with R-13 Insulation

_____
Permit Number

MEC*check* Compliance Report

_____
Checked By/Date

MEC*check* Software Version 3.0 Release 1
2000 IECC Edition

CITY: Pittsburgh
STATE: Pennsylvania
HDD: 5968
CONSTRUCTION TYPE: Single Family

DATE: 02/05/01

COMPLIANCE: Passes

Maximum UA = 327
Your Home = 320

	Gross Area or Perimeter	Cavity R-Value	Cont. R-Value	Glazing or Door U-Factor	UA
Ceiling 1: All-Wood Joist/Rafter/Truss	1418	38.0	0.0		43
Exterior Wall 1: Wood Frame, 16" o.c.	1274	13.0	5.0		82
Door 1: Opaque	56			0.390	22
Window 1: Vinyl Frame, Double Pane with Low-E	246			0.400	98
Exterior Wall 2: Wood Frame, 16" o.c.	160	13.0	0.0		13
Floor 1: All-Wood Joist/Truss, Over Unconditioned Space	1418	21.0	0.0		62

COMPLIANCE STATEMENT: The proposed building design described here is consistent with the building plans, specifications, and other calculations submitted with the permit application. The proposed building has been designed to meet the 2000 IECC requirements in MEC*check* Version 3.0 Release 1.

Builder/Designer_____ Date_____

Attachment 9

Garage Wall with R-18 Insulation

_____
Permit Number

MEC*check* Compliance Report

_____
Checked By/Date

MEC*check* Software Version 3.0 Release 1
2000 IECC Edition

CITY: Pittsburgh
STATE: Pennsylvania
HDD: 5968
CONSTRUCTION TYPE: Single Family

DATE: 02/05/01

COMPLIANCE: Passes

Maximum UA = 327
Your Home = 317

	Gross Area or Perimeter	Cavity R-Value	Cont. R-Value	Glazing or Door U-Factor	UA
Ceiling 1: All-Wood Joist/Rafter/Truss	1418	38.0	0.0		43
Exterior Wall 1: Wood Frame, 16" o.c.	1274	13.0	5.0		82
Door 1: Opaque	56			0.390	22
Window 1: Vinyl Frame, Double Pane with Low-E	246			0.400	98
Exterior Wall 2: Wood Frame, 16" o.c.	160	13.0	5.0		10
Floor 1: All-Wood Joist/Truss, Over Unconditioned Space	1418	21.0	0.0		62

COMPLIANCE STATEMENT: The proposed building design described here is consistent with the building plans, specifications, and other calculations submitted with the permit application. The proposed building has been designed to meet the 2000 IECC requirements in MEC*check* Version 3.0 Release 1.

Builder/Designer_____ Date_____

Attachment 10

U-0.55 Skylights

_____
Permit Number

MEC*check* Compliance Report

_____
Checked By/Date

MEC*check* Software Version 3.0 Release 1
2000 IECC Edition

CITY: Pittsburgh
STATE: Pennsylvania
HDD: 5968
CONSTRUCTION TYPE: Single Family

DATE: 02/02/01

COMPLIANCE: Passes

Maximum UA = 327
Your Home = 318

	Gross Area or Perimeter	Cavity R-Value	Cont. R-Value	Glazing or Door U-Factor	UA
Ceiling 1: All-Wood Joist/Rafter/Truss	1418	38.0	0.0		43
Exterior Wall 1: Wood Frame, 16" o.c.	1434	13.0	5.0		92
Door 1: Opaque	56			0.390	22
Window 1: Vinyl Frame, Double Pane with Low-E	238			0.400	95
Window 2: Vinyl Frame, Double Pane with Low-E	8			0.550	4
Floor 1: All-Wood Joist/Truss, Over Unconditioned Space	1418	21.0	0.0		62

COMPLIANCE STATEMENT: The proposed building design described here is consistent with the building plans, specifications, and other calculations submitted with the permit application. The proposed building has been designed to meet the 2000 IECC requirements in MEC*check* Version 3.0 Release 1.

Builder/Designer_____ Date_____

Attachment 11

U-0.40 Skylights

_____
Permit Number

MEC*check* Compliance Report

_____
Checked By/Date

MEC*check* Software Version 3.0 Release 1
2000 IECC Edition

CITY: Pittsburgh
STATE: Pennsylvania
HDD: 5968
CONSTRUCTION TYPE: Single Family

DATE: 02/02/01

COMPLIANCE: Passes

Maximum UA = 327
Your Home = 317

	Gross Area or Perimeter	Cavity R-Value	Cont. R-Value	Glazing or Door U-Factor	UA
Ceiling 1: All-Wood Joist/Rafter/Truss	1418	38.0	0.0		43
Exterior Wall 1: Wood Frame, 16" o.c.	1434	13.0	5.0		92
Door 1: Opaque	56			0.390	22
Window 1: Vinyl Frame, Double Pane with Low-E	238			0.400	95
Window 2: Vinyl Frame, Double Pane with Low-E	8			0.400	3
Floor 1: All-Wood Joist/Truss, Over Unconditioned Space	1418	21.0	0.0		62

COMPLIANCE STATEMENT: The proposed building design described here is consistent with the building plans, specifications, and other calculations submitted with the permit application. The proposed building has been designed to meet the 2000 IECC requirements in MEC*check* Version 3.0 Release 1.

Builder/Designer_____ Date_____